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Photographic Illumination in Motion Picture Studios*

By F. V. HAUSER, Assoc. I.E.E. *(Member)*,† F. S. HAWKINS, Ph.D., A.R.I.C.,‡ and W. R. STEVENS, B.Sc., A.M.I.E.E. *(Fellow)*‡

Synopsis

The conventional method of lighting a motion picture set is described, together with the illumination levels needed and the spectral distribution of the light, and from these factors the general requirements are deduced for lighting fittings using tungsten filament, carbon arc and high pressure mercury vapour discharge lamps. A more detailed account is then given of the way in which each of these sources is employed in order to satisfy the general requirements. The design of prismatic lenses, external attachments for light control, efficiency and colour of high intensity arcs, the double negative arc, operational requirements of discharge lamps, and thermal and mechanical design problems are discussed. They show what is accepted good practice at the present time and where future development may occur. A short closing section on supplies for studio lighting discusses the effect of ripple in the electrical supply voltage on generating noise in the flame of a carbon arc.

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(1) Introduction

The work of creating a photographic record of the settings and action of a feature motion picture is more than a mere matter of obtaining a consistently exposed negative which clearly shows what is taking place. In addition the lighting cameraman must be able to accentuate what is required by

* Manuscript received on February 26, 1948. Presented at a meeting of the Society on April 13, 1948.
† Denham and Pinewood Studios, Ltd.
‡ Research Laboratories of the General Electric Company, Ltd., Wembley.

the director for the proper development of the story and by his lighting depict the various scenes in a key which will add to dramatic intensity. To be fully successful, therefore, his photographic treatment of a story calls for some imaginative power allied to an extremely keen sense of light values and intensities. In spite of all the aid he can obtain from photometers and other devices, it is this specially keen sense which enables him to add those slight touches to his lighting which singles him out as a feature film photographer. This is not a divine gift, but is acquired by the comparative few after a long and painstaking acquaintanceship with the practice of set lighting, whereby they progress from camera assistants to camera operators, finally graduating as lighting cameramen. Anyone who has been closely associated with the top ranking lighting cameramen in this country, and has watched their development over a number of years, must have the greatest admiration for the sure touch they have acquired, whereby, in picture after picture, and year by year, their work stands out above the average. These men are always striving for perfection and this is one reason why studio lighting never stands still and why there is always a call for better and more convenient lighting sources and equipment.

(2) Basic Requirements of Studio Lighting

(2.1.) Method of Lighting a Set

The fundamental requirement is that luminous flux should be directed in sufficient quantity at will on the various portions of the set. Direction of the flux is obtained by the proper handling of individual lighting fittings, which are mobile and are equipped with the necessary facilities for adjustment. The general procedure for lighting a set is as follows.(1) (2) (3)

The chief set electrician has the lamps placed in position on cradles around

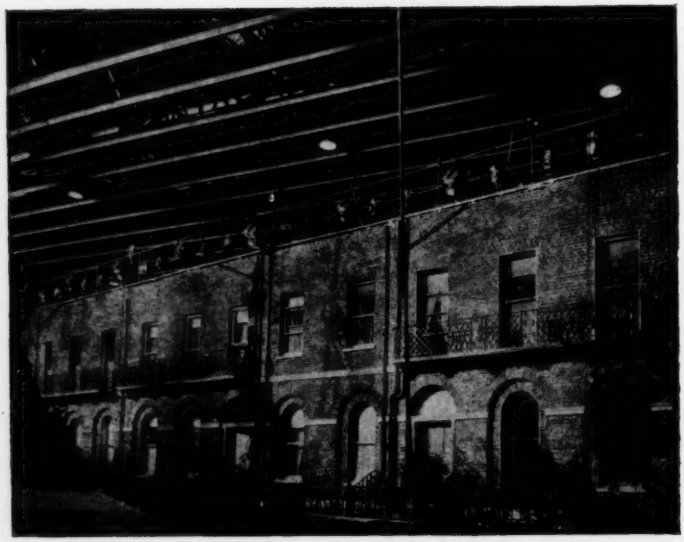


Fig. 1. Incandescent units rigged for "low key" lighting of an exterior scene built inside a studio.

Fig. 2. 'Low key' lighting of a composite interior set with incandescent units only.

the top edges of the set and also on the floor, in accordance with established practice, but bearing in mind the lighting cameraman's requirements for the particular nature of the scenes to be photographed. This work is carried out by a group known as the "Rigging Crew," and the aim is, as far as possible, to have at least one set prepared in advance so that it is ready for the director as soon as he has completed his previous set. Depending on the size and importance of the setting, the lighting cameraman will be able to arrange his key lighting before the set is ready for shooting and on changing over to shooting he will then modulate the illumination of the other areas of the set either by increases or decreases in the lighting values or by rearrangement of some of the equipment employed. He quickly achieves the lighting balance required and a first-class man will do this instinctively, purely by an assessment of the values by eye, without the aid of a meter beyond the setting of his key light. (Figs. 1, 2.)

The attainment of a suitable "balance" is very largely an artistic effect and while this varies with different feature cameramen the effect produced is equally pleasing. To assist in achieving this result rapidly and to save time in making the necessary changes when the "set up" or angle included by the camera lens is altered, more lamps are rigged on the set than are required for any one scene. On exceptionally large settings the procedure outlined may be varied somewhat, as in these cases it is invariably necessary for the lighting cameraman to prepare his long shot lighting in advance. In such a shot there may be as many as two hundred separate lighting units to adjust, and this naturally requires more time being devoted to obtaining the subtle distinctions in intensity which compose the picture. This may take part or the whole of a day in special cases.

With colour production, the same general methods are employed in set lighting, but in this case the number and power of the lighting units is stepped up.

It follows that the lighting fittings for all general purposes in studio lighting, whether the film be black and white or in colour, need to have certain features in common. They must be transportable and of such dimensions that they can be rigged upon cradles possibly 35 feet above floor level; and in order

to avoid unreasonable multiplicity of types most of the fittings should be capable of providing a wide range of light distributions.

From this it will be seen that the basic requirement of studio lighting equipment is adequate control. By this is meant not only that the units employed can be raised or lowered, tilted or rotated with ease, and can be readily varied as to intensity and width of beam, but also that by diffusion, dimming and arrangements for the restriction or shadowing of part of a beam, any effect desired can be accomplished without undue delay.

The fittings used to achieve this end can be divided into two general types; spotlights in which the divergence of a well-defined beam is varied over a range of about 10 deg. to 50 deg., and general lighting units (broadsides, scoops, etc.) which give a wide beam whose divergence cannot normally be varied. As the fittings are transportable and are wired with what are, in effect, temporary cables, it is a Home Office requirement that unless they are earthed they must be supplied with power at a voltage not exceeding 140 volts D.C. That most commonly used is 115 volts D.C. Other obvious requirements are robustness, ease of handling, lightness in weight, and comparative coolness during operation. Because sound is generally recorded at the same time as a shot is taken, it is necessary that the fittings should be quiet in operation.(4)

(2.2.) Illumination Required

With the present panchromatic negative film stock, for black and white photography, "key intensities" of from 80 to 120 lumens per square foot are usual, although for special types of photography these may be considerably increased. For example, in "deep focus" photography, where the camera lens is stopped down to a small aperture, the illumination may be at least 10 times these values. "Key intensity" refers to the illumination falling on the principal artists in the particular scene, or on objects which are intended to be featured, and does not in any way refer to the general illumination level of the set, which may vary considerably in different portions. While the general technique of set-lighting for colour photography remains basically the same, the illumination levels are necessarily much higher, and in this case the use of the illumination meter is extended not only to establish the high light levels, but also the shadow values. "Key intensities" for Technicolor vary between 500 to 1,000 lumens per square foot, and higher.

The required range of intensities and distributions is obtained by the use of fittings ranging from the 100 watt "Dinky Inky," using a tungsten filament lamp to the 17 kw. high intensity arc lamp, but the fittings most commonly used employ the 2 kw. incandescent for black and white, and the 150 ampere arc for colour photography.

(2.3.) Spectral Distribution of the Light

For black and white photography the colour rendering properties of the light are important only in so far as they disturb the truth of the monochrome rendering, but for colour photography, using the processes available for 35 mm. film, the light must have a spectral distribution equivalent photographically to that obtained from the sun when open air shots are taken. As a result the bulk of black and white photography is taken using incandescent lighting, but for colour film most of the light is supplied by high intensity arc lamps.(5)

(3) Types of Light Source Available

(3.1.) Incandescent Tungsten Lamps

For black and white photography these lamps are used in powers and sizes ranging from 100 watts to 5 kw., their lumens per watt ranging from 22 to

28, with an average life of 100 hours, at colour temperatures between 2,900 deg. K and 3,200 deg. K.

Tungsten filament lamps are also employed in colour photography for close-ups and for positions close to the microphone. For this purpose special C.P. (colour photography) lamps are employed in which the colour temperature is increased to 3,400 deg. K. These lamps have only a 10-hour life and are used in conjunction with Cobalt blue glass filters designed to absorb the excess red-orange light. The comparatively low output of such sources renders them suitable only for the lighting of very small areas, and whilst in Hollywood whole sets have been lit by these methods, the lamp replacement cost has been found to be excessive. In addition the power consumed and the heat produced in lighting a set to the required level of 500 to 1,000 lumens per square foot are very great, making conditions uncomfortable for the artists.

(3.2.) Carbon Arc Lamps

Before panchromatic stocks were available, the film was sensitive only to the blue and near ultra-violet end of the spectrum. In this country, prior to 1919, plain carbon arcs, burnt in lamps such as the Westminster, together with low pressure mercury lamps, were used almost exclusively for set lighting. The Westminster type of lamp was followed by various forms of white flame arc which had been developed in the U.S.A. during the period 1914-1918. With the advent of panchromatic film, around 1926, however, the tungsten filament lamp superseded these early light sources and the use of the carbon arc was restricted to special effects, such as those requiring strong shadows to be cast, as when the sunlight streams through a window. To-day, it still occupies this position in the black and white field, but the introduction of colour processes suitable for professional use, and the development of a full range of high intensity arcs giving light of an appropriate colour, brought the carbon arc back into use as the main light source for colour film production. Colour filters, where employed, are not very dense and as the efficiency of the light source is high, the appropriate level of illumination can be conveniently realised. Lamps of the high intensity type have their carbons advanced by a motor-driven mechanism, and care must be taken in its design to secure quietness of operation and the uniformity of feed necessary to maintain the maximum steadiness of light output. Some smoke and fume from this type of arc seem to be inevitable.

(3.3.) High Pressure Mercury Vapour Lamps

Low pressure mercury vapour lamps became redundant when panchromatic film was introduced. The use of a higher pressure of mercury vapour, however, gives an efficient lamp with a light that is more actinic with respect to panchromatic stock. Trials with such lamps were being made about 1939.(6) Work was re-started after the war, particularly with colour modified lamps, in which the introduction of cadmium and zinc into the arc was found materially to improve the colour rendering properties of the lamp. There appeared a possibility that this illuminant would be suitable for colour photography, and early in 1945 tests of a single colour corrected lamp were made at Denham studios. The response was so satisfactory that it was decided to make a full-scale test against arc lighting as soon as sufficient lamps were available. These tests took place later in the year and demonstrated that the colour corrected discharge lamp, in spite of its limited spectrum, gave almost exactly similar results to the high intensity carbon arcs, with the Technicolor three-colour photographic system with which the tests were made.(7)

The experimental full-scale tests which are now in progress have shown

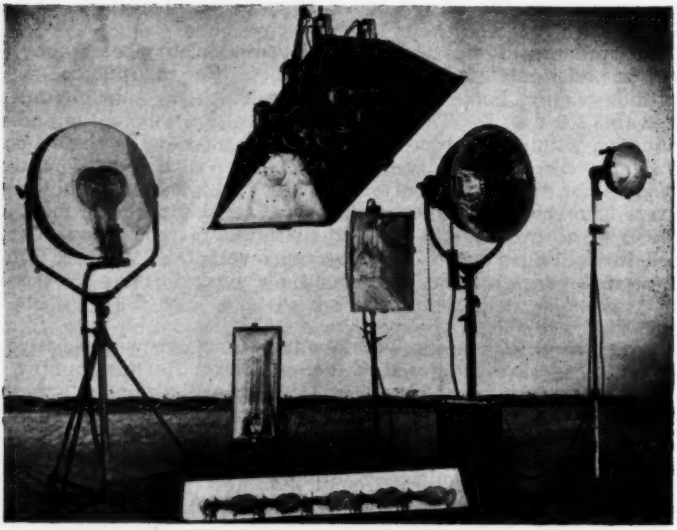


Fig. 3. Incandescent flood lamps.

that such a lamp provides a highly efficient source, silent in operation and free from smoke and fume. There are, however, some operational difficulties at present associated with the running of these lamps, such as the length of the run up time from a cold start, and the high voltage of the pulse required to start them when hot.(8)

(4) Incandescent Lamp Units

(4.1.) Optical Requirements

Incandescent lamps are the most convenient of the available light sources. They are silent, emit no smoke; they are light in weight and easy to handle, and require no auxiliary gear. They are excellent for taking black and white films but for colour films need a blue filter of some 50 per cent. transmission.

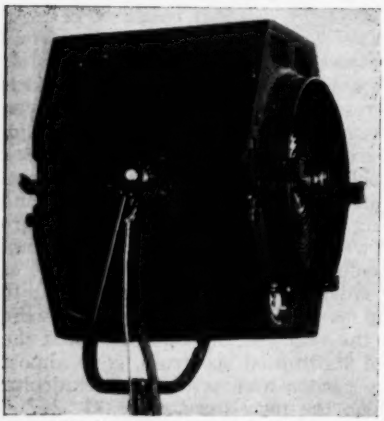


Fig. 4. Incandescent spot lamp.

Identical fittings are used for black and white and colour films. The broadside or floodlighting type of fitting uses a diffusing reflector giving a widespread distribution of light. The shape of the fitting is dictated by mechanical convenience rather than by optical requirements; its reflecting surface is generally white enamel or aluminium paint. It is used for lighting large areas, such as backings, and to fill in and soften shadows.

Fig. 3 shows a group of such fittings which use lamps of 500 watts to 1,500 watts.

Of more importance is the type of unit in which light control is effected by a prismatic lens (Fig. 4). The lens may be flat or domed and has circumferential prisms. The design is such that the beam may be varied from narrow to wide divergence by adjusting the position of the lamp relative to the lens; generally the beam angle can be varied from 10 deg. to 45 deg. total spread. It is essential that the light distribution be smooth across the beam so that no streakiness shows in the picture. The sharpness with which light is cut off at the edge of the beam is also a matter of some importance. In such a lens the best prism formation for the spot position is not that for the spread position. If a lens is designed to get a smooth spread distribution (with the lamp close to the lens) it is found that as the lamp is withdrawn from the lens, the beam tends to have a bright core with a less bright halo. This is because rays passing through the lens a little off the centre, tend to converge rapidly, and cross over the optical axis of the system before the outer rays have reached their minimum divergence.(9)

Conversely, a lens designed to give a good concentrated beam tends to show a dark spot in the spread beam position. As with so many prismatic designs, therefore, the designer must select the compromise which seems most suitable, and modern lenses give very satisfactory results (Fig. 5). The lens pick up at full spread is about 120 deg. and a backing mirror is used to increase

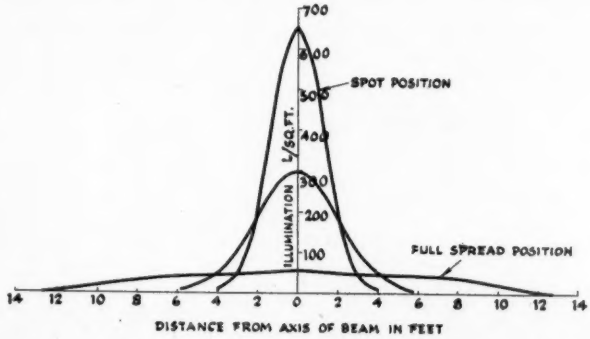
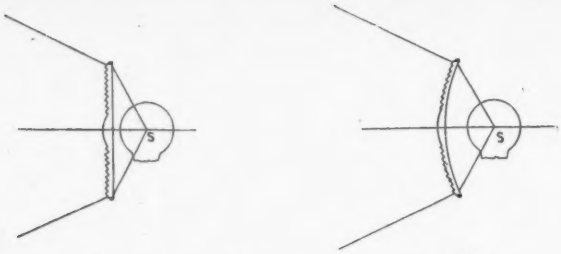


Fig. 5. Illumination curves from 2 kw incandescent spotlight on a plane 25 ft. from the lens.

the fitting efficiency. Flat grid filament lamps of 500, 2,000 and 5,000 watts are used with lenses of diameter 6, 10, and 14 inches respectively.

Domed lenses have some advantages in that doming tends to equalise the distance of the light source from the centre and edges of the lens, and radiant heating is, therefore, more uniform. On the other hand, bending of light at the lens edges is rather more difficult with a domed lens, since light falls on the inner face more nearly normal than with a flat lens; hence, more bending of light must be done by the prismatic (exterior) face, and the losses are slightly greater (Fig. 6).

The stippling applied to the back of the lens is of considerable importance. It generally consists of little knobs resulting from circular depressions in the mould, but sufficiently close to appear as an hexagonal pattern. Other forms, such as flutes, have been tried with the object of reducing the streakiness



(a) (b)

Fig. 6. Comparison of flat and curved refractor plates.
(a) Flat plate—more efficient light control, less even heating.
(b) Curved plate—less efficient light control, more even heating.

inevitable in a stepped lens of this design, without seriously affecting the light distribution.

Stepped lens equipment was introduced to this country in 1936 and revolutionised existing methods which had previously been based on the parabolic mirror and plano-convex condenser lens. Objections to lighting with mirror sources were due to the difficulties encountered in obtaining even "coverage" because of the higher intensity obtained from the area adjacent to the periphery, together with the darker centre of the beam. Even when heavily diffused this feature was still apparent so that the brighter centre of the beam from the Fresnel lens, which tapers off to a soft edge, was much more acceptable. No longer were cameramen faced with the difficulties created by artists moving in and out of narrow bands of light. Although mirror-type optical systems are capable of giving suitable light distribution, they do not lead easily to a simple and robust mechanical design as do refractor plate systems.(9)

A form of unit which found favour for a short time was the "Klieglight." This was essentially a "magic lantern" optical system which projected a sharp-edged beam of light and was useful, for example, for lighting through a window or door where no light was wanted on the surrounds. An ellipsoidal mirror condenser system was used and a simple projection lens. The fitting was generally fitted with an adjustable aperture so that various simple shapes of light patch could be produced; alternatively metal cut-outs could be inserted to give any desired beam shape. Although useful, this fitting has never been important because of the low intensities which it gives; it is inherently an inefficient optical system.

(4.2.) Mechanical and Thermal Requirements

The main mechanical requirements of incandescent fittings, as of all others, are that they should be robust, light and easy to handle, and that they should keep reasonably cool. These are all problems with which the lighting fitting designer is familiar, although few pieces of lighting equipment get such severe handling as those in a motion picture studio. The design of the fittings now in use has been based on long experience; it is nearly impossible to guess at every form of damage which may occur. Sheet steel is used in the construction of some fittings, but others, particularly of recent design, use pressed sheet aluminium and light alloy castings.(9)

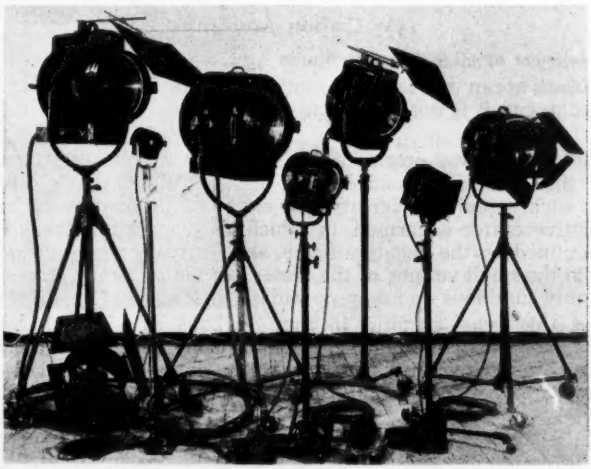
It is desirable that fittings should be as cool as possible, and this applies particularly to focusing and locking handles. Good ventilation is a great help: to be most valuable it must be effective for all burning positions, from vertically

down to vertically up. A lens fitting probably spends most of its life directed at about 45 deg. below the horizontal, and the ventilation system must be designed with this in mind. Another device of great help in keeping the sides cool is an inner skin separated by an air space of about 1 inch from the outer wall, and preventing direct radiation from the lamp from falling on it. By this means the outer wall temperature may be reduced some 25 deg. C. from, say, 85 deg. C. to 60 deg. C. Since the largest tungsten lamp used in the film studio takes 5 kw. the problem is not so serious as with high intensity arcs, where thermal lagging is often used.

The most usual thermal difficulty is the "drawing" of lamp bulbs. Between the lamp bulb and the metal backing mirror a pocket of hot air is formed; in bad cases this softens the bulb which blows outward into a blister. The effect is aggravated when the fitting is directed below the horizontal and is sometimes serious enough to persuade studios to remove the backing mirror altogether.

(4.3.) Attachments for Light Control

In the motion picture studio, lighting fittings may be equipped with a variety of external light controlling devices with curious names—snoots, diffusers, etc.



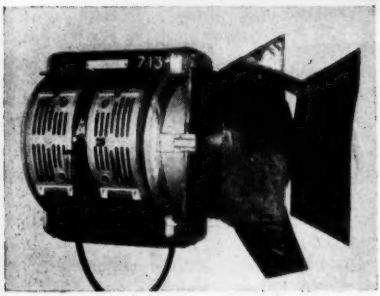


Fig. 7. (a) *(above)* Incandescent spot-lamps with detachable flags, barn doors and snoots, (b) *(left)* High intensity arc lamp with barn door snoot.

Some of the more commonly used attachments are:—

(a) Diffusers —translucent media such as waxed paper, frosted gelatine, jap silk.

(b) Snoots —tubular funnels limiting the spread of light.

(c) Lead Snoots—used on the smaller units. A similar device to the snoot made in soft metal or thin sheet, whose cross-section can be altered by hand to give a light patch of definite shape.

(d) Barn-doors—Snoots with four doors at the end, further to restrict the lighted area.

(e) Niggers —Pieces of opaque material for cutting off part of the beam.

Such devices, illustrated in Fig. 7, are largely peculiar to individual studios or individuals; they are combinations of art and science—generally art is predominant—and have been shown to give the required results. Although some of these additions seem crude, their justification is that they work. Chromium-plated knobs would not be likely to improve matters, unless the lighting cameramen were fond of chromium-plated knobs. It is sometimes suggested that such devices should be built permanently into standard fittings, but the difficulty of finding requirements common to all users makes this practically impossible.

(5) Carbon Arc Units

(5.1.) Development of High Intensity Studio Arc Lamps

The carbon arc in one form or another has always been used in the motion picture studio, and it is not surprising that the high intensity arc found favour rapidly.

This arc, which was originated by Beck during the 1914-18 war, employs a positive that is heavily loaded with light-emitting salts. It is burnt with conditions, such as current density and electrode disposition, so arranged that a deep positive crater is formed, in which the vapours of the light-producing salts are confined by the negative flame, and heated by the considerable power dissipated in the small volume of the crater. In these circumstances, the vapours become highly luminous and may nowadays attain a brightness of 200,000 stilb.

Arcs of this type burning 16 mm. carbons at 150 amperes were first developed for searchlights, and were at one time used for cinema projectors. Smaller arcs, ranging in size from the above down to those employing 6 mm. positives at 35 amperes, gradually evolved, and various arcs within this range

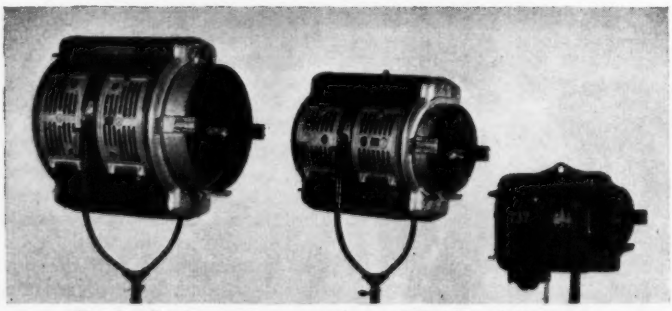
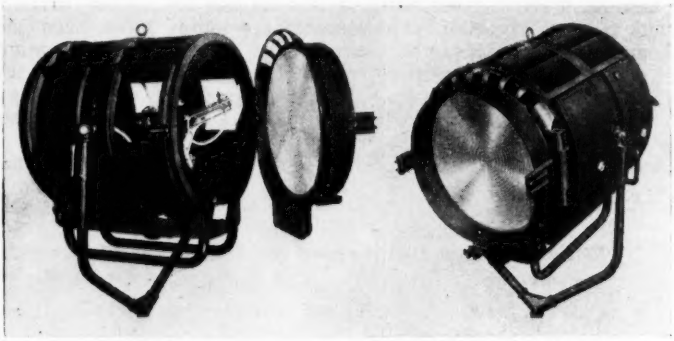
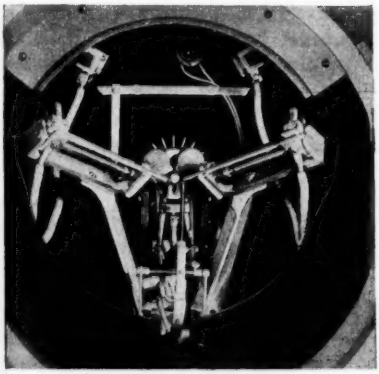


Fig. 8. Single negative arc spotlamps, 150, 120 and 65 ampere.



(a) (b)



(c)

Fig. 9. Double negative 150-ampere arc spotlamp.

(a) exterior.
(b) lamp open.
(c) showing arrangement of carbons.

of sizes were adapted for studio lighting when colour processes came into use. (Fig. 8, 9, 10.) [10] [11] [12]

(5.2.) Specification of Studio Arc Lamps

It is convenient to define the power of a lamp by specifying the watts it consumes, and for lamps which must be supplied with power at a particular voltage, this is clearly the most suitable method. Arc lamps, however, are always used with a resistance connected in series; it may be large, sometimes it is very small, but by the simple adjustment of a tap on the resistance the arc can be made to function equally well on a number of different line voltages and so absorb correspondingly different amounts of power from the supply mains. The arc voltage, current, and hence the power dissipation remain constant, and so would at first sight appear to be suitable for specifying the arc; but if this be done it is not possible to discover from the specification figure just how much power is taken from the mains by the complete lamp and resistance. The current through the arc also remains constant, and if this be used for specification the power drawn from the supply can readily be obtained, for the supply voltage is almost invariably known.

Voltages of supplies for cinema projectors vary from one installation to

another, and so it has become usual to specify the arc by its current rather than by its power. For like reasons studio arc lamps have been similarly specified, and if, in addition, the diameter of the positive and number of negatives are quoted, the specification conveys to the experienced user the power absorbed by the arc and its ballast resistance, and also enables him to make an estimate of the size of the light source, its brightness, and consequently its output of luminous flux.

The existing range of high intensity arc spot lamps when so specified is as follows:—

Table 1

Existing Range of High Intensity Arc Lamps (Spotlights)

Current		*Positive carbon size*		
225	amperes	16	mm.	(Single negative).
150	„	16	„	(Double negative).
150	„	16	„	(Single negative).
120	„	13.6	„	„ „
65	„	9	„	„ „

The limitations imposed by layout of lamp mechanism and polar distribution of the light from the high intensity arc, while they make it very suitable for spot lights, render it less convenient for incorporation in broadsides or scoops. A modified form of white flame lamp has been successfully employed for this purpose, burning an 8 mm. positive at 40 amperes. (Fig. 10.)

(5.3.) Salient Properties of Studio Arc Lamps

Studio arc lamps are made of three major components, the lamp mechanism, the refractor, and the housing. The necessary requirement of a lamp mechanism is that it will burn the arc silently and steadily for a variable period of time, which may extend from a few minutes to the full duration of burn of the longest carbons that can be trimmed in the lamp. To secure the required degree of steadiness and silence the positive of the high intensity arc needs to be rotated and fed forward; the negatives are fed without rotation.

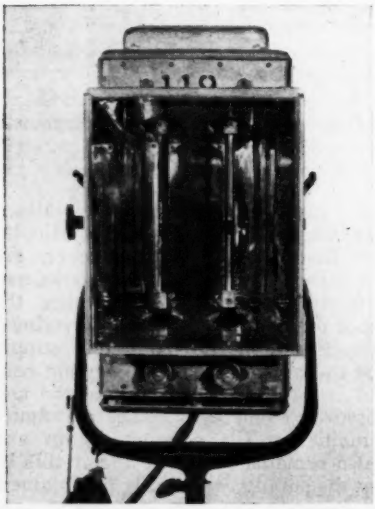


Fig. 10. 40-ampere twin arc floodlamp. (Front glass removed.)

The positive feed and rotation are obtained by a mechanism of the type illustrated in Fig. 11, in which the carbon is gripped between two gear wheels, and, as they turn, they feed it forward. They are slowly turned by a gear train in a small gear box, and rotation of the carbon is secured by rotating the complete gear box.

The negatives are fed by an independent gearing, and the whole mechanism is driven by a small electric motor. Special precautions taken to secure silent operation of the mechanism include the mounting of

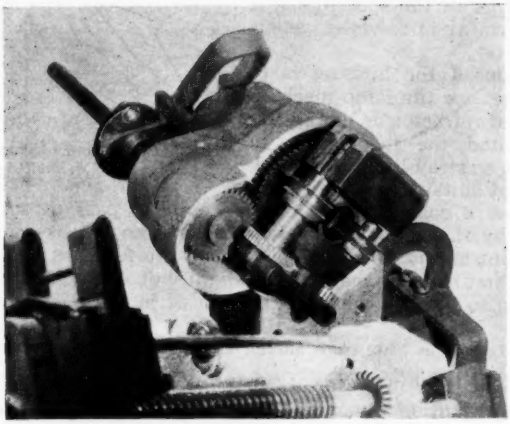


Fig. 11. Positive feed mechanism of arc lamp.

the motor and fast-moving gearings on acoustic insulation, and the employment of a motor in which such sources of noise as brush chatter and magnetic hum are reduced to a minimum.

Most arc lamps are semi-automatic in that the voltage across the motor is the same as the voltage across the arc gap. An increase in arc gap causes a rise in voltage, and there follows a compensatory increase in feed rate of the carbons. A fully automatic form of arc control has recently been described, in which the position of the positive crater is controlled by forming an image on a sensitive device, such as a bimetallic strip, which by its action alters the speed of positive feed, and the position of the negative is determined by making its feed dependent in both speed and direction upon arc voltage.(13) (14) (15)

The white flame arc lamps have their arc gap controlled, like the negative in the above system, by a motor which feeds the carbons at a speed and in a direction controlled by the voltage across the arc gap. Before the arc is struck the voltage across the gap is above the pre-set value and the carbons approach until they touch. When this happens the arc voltage drops below the pre-set amount, and so the direction of feed is reversed and the arc gap opens until the correct arc voltage is established. Variations in arc length during burning are corrected by the same mechanism. As this arc has not to be maintained at the focus of an optical system no precautions are taken in these lamps to ensure that the position of the arc in the fitting is maintained within close limits.(11)

The refractors which are used in arc spot lamps are Fresnel type pressed lenses made of heat-resisting glass and ranging from 8 inches in diameter for the 65-ampere arc to 24 inches diameter for arcs of 225 amperes. They give a beam which can be concentrated to a spot of approximately 8 deg. divergence or spread to a wide beam of approximately 45 deg., the increase being obtained by moving the arc lamp mechanism so that the crater travels towards the lens from a point close to the focus by a distance of about half the focal length.

No refractor is required for the broadsides, but a sheet of lined, or otherwise patterned, glass covers the open side of the lamp. This enables a more uniform distribution of light to be obtained over a divergence of 90 deg., and,

like the refractors in the spot lights, it absorbs the harmful ultra-violet generated by the arcs.

The function of the housing is to provide a support for the lamp mechanism, controls and refractor or lined glass sheet, to surround the mechanism in such a way that no stray light is emitted, and by means of suitable apertures and louvres, to allow a considerable volume of air to pass through by the convection set up by the arc. The passage of such an air stream serves to cool the lamp mechanism and housing and remove arc fume as it is generated. A form of louvre that is proof against stray light, but is light in weight and offers little obstruction to the flow of air, is illustrated in Fig. 12.

Fig. 12. Outline of top louvre for arc lamp.

(5.4.) Output of Luminous Flux from Studio Arc Lamps

(5.4.1.) *Intensity of the Flux*

The light distribution given by any fitting is determined by the size and brightness distribution of the light source and by the properties of the optical system used. As a result of the steady improvement in carbons during recent years, differences between the arcs given by carbons of the same rating, obtained from different sources, are comparatively small. Polar curves for the range of arc lamps have been published and may, therefore, be taken as representative. Typical values given are tabulated below.(10) (16)

Table 2

Lamp	Full Spot		Full Flood	
Spotlights	Peak Candles	Divergence	Peak Candles	Divergence
225 amps. 16 mm. positive	10×10^6	12 deg.	1×10^5	48 deg.
150 amps. 16 mm. positive (single negative) ...	5.7×10^6	10 deg.	0.35×10^6	48 deg.
150 amps. 16 mm. positive (double negative) ...			0.30×10^6	51 deg.
120 amps. 13.6 mm. positive	2.0×10^6	10 deg.	0.13×10^6	44 deg.
Floodlights	Peak Candles		Divergence	
40 amps. 8 mm. positive...	33,000		90 deg.	

The peak candles and divergences given by the spotlights are determined by the light output from the arc and the optical properties of the refractor. The contribution made by the arc to the peak candles can be estimated by the use of the relationship shown in Fig. 13 in which peak mega-candles for a given divergence are plotted against kilowatts in the arc for four different arcs each using identically the same optical system. It shows that over the range of powers covered by these arcs the peak candles are approximately proportional to the power input to the arc, provided there is no change in the light distribution in the beam. The latter changes with different refractors; the curves shown in Fig. 14 illustrate the polar distributions given by two different makes of refractor giving beams of equal divergence from the same arc. Changing

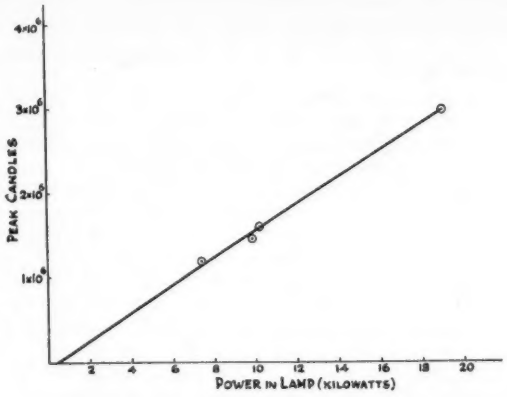


Fig. 13. Relation between peak candles and power input for 150-ampere arc lamp with 20″ diameter refractor.

only the arc power, however, does not change the shape of the polar distribution by a significant amount.

In these circumstances the use of larger and more powerful arcs in place of the usual 150-ampere arc will need fewer fittings to light a given set, but unless better optical systems are used or economy of luminous flux is obtained, e.g. by decreasing the amount of light wasted on unwanted portions of the set, there will be no change in the total amount of arc power required. Decrease in the total power required to light the set can be obtained either by wasting less in the ballast resistances or grids, by an increase in the efficiency of the

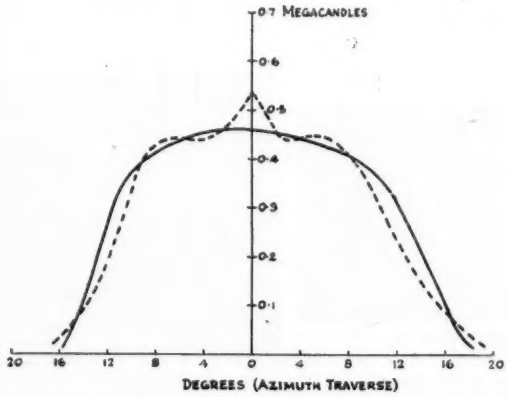


Fig. 14. Polar curves of two different refractors in the same 150-ampere arc lamp.

optical system or by the more efficient usage obtained from a smaller number of fittings.

(5.4.2.) *Colour of the light*

Although there are many lines in the spectrum of the crater light of the high intensity arc, there is also much continuous radiation, and the overall effect is that the spectral distribution in the visible portion of the spectrum is fairly close to that of a black body at 5,500 deg. K.[17]

A very important property of an illuminator for use in a colour film process is its colour rendering, as interpreted by the particular colour process used. The best method of determining this property is to make test exposures, using the particular colour process involved. This requires fairly elaborate experimentation. It is often of value to measure the colour of the light, and in some circumstances these measurements give useful results, although they are no substitute for a full determination of spectral distribution. Such circumstances arise when small changes in the colour of the light from a high intensity arc lamp occur, such as may result from minor changes in core composition or method of manufacture. They are not the result of any fundamental change in the process of light emission and it has proved convenient and reliable to measure the chromaticity co-ordinates of the light from these arcs and use them as a guide to the colour rendering properties. As an example of these measurements the following table contains the chromaticity co-ordinates, measured with a Donaldson colorimeter, of arcs from a selection of carbons. All of these measurements were made with the arc in the complete fitting, and in each case the fitting had also been tested and found satisfactory by taking test exposures and printing colour film of the tests.

Table 3

Arc	X	Y	Z
120 ampere 13.6 mm. positive...	0.320	0.296	0.384
150 ampere 16 mm. positive single negative type 16	0.327	0.332	0.341
150 ampere 16 mm. positive double negative type 19	0.326	0.331	0.343
150 ampere 16 mm. positive double negative type 124	0.325	0.341	0.334

It is customary to use a light straw coloured filter (Y.1) in front of the spotlight refractor and its effect on the colour of the light is shown by the following values of the chromaticity co-ordinates for a 120-ampere 13.6-mm. arc using this filter:[18]

$$X = 0.349 \qquad Y = 0.357 \qquad Z = 0.294.$$

(5.5.) Efficiency of Studio Arc Lamps

The high level of illumination required for colour photography makes a high luminous efficiency a very desirable attribute in the illuminant, and this is best expressed as the amount of power dissipated for the incidence of unit amount of light on the set. The evaluation of the efficiency according to the above definition should include the power absorbed by the ballast resistance as well as that absorbed by the arc.

Full details of the luminous efficiencies of the various types of arc lamp do not appear to have been published, but it is possible to construct from the data available in the literature a table of the efficiencies of the 150-ampere arc spotlight that is approximately correct.[13] [19]

Table 4

Efficiency of the 150-ampere spotlight (Single negative)

Method of calculation	*Lumens/watt*
Total luminous flux/ Watts absorbed by arc	49
Total luminous flux/ Watts taken from generator	31
Luminous flux in beam at full flood/ Watts from generator	8
Luminous flux in beam at full spot/ Watts from generator	3

A type of arc lamp has recently been developed in this country in which a stable arc is obtained using in place of the orthodox single negative two negatives pointing slightly downwards and separated by an angle of 100 deg.(9) The advantages obtained by the use of the additional negative are twofold, a reduction of arc voltage, from 65 to 50 volts, and a decrease of arc noise. The reduction of arc voltage, which results from the stability of this arc at an arc gap of less than normal length is sufficient to allow two of these lamps to be run in series from the 115-volt studio mains, and figures similar to the above for the efficiency of two of these lamps in series show a considerable improvement, as the loss in the ballast resistance is reduced to a very small proportion of the total power.

Table 5

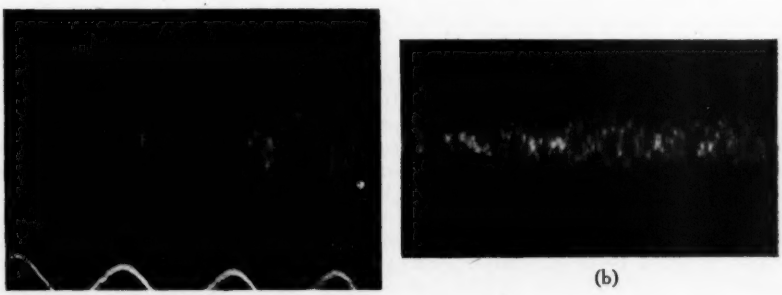
Efficiency of two 150 double negative arc lamps running in series

Method of calculation	*Lumens/watt*
Luminous flux in beams at full flood/ Watts from generator	14
Luminous flux in beams at full spot/ Watts from generator	5

All of these efficiencies, which are approximate only, are rounded off to the nearest integer.

(5.6.) Quietness of High Intensity Arc Lamps

The permissible amount of noise from a studio arc lamp is quite low. Lamps now in use have, when correctly operated, noise levels 2 ft. from the crater



(a) (b)

Fig. 15. Oscillograms showing effect on noise of different types of brushes in an arc lamp motor.

(a) Unsuitable brushes (with 50 cycle timing wave). (b) Suitable brushes.

of the order of 10 phons,* and this is achieved in spite of the fact that the arc lamp is a device in which quantities of carbon, cerium fluoride and copper are rapidly boiled in the arc, while at the same time a small electric motor is driving a train of gears to rotate and feed the electrodes.(9) (18) (20)

The noise from an arc lamp may be broadly divided according to its source into the noise made by the arc and that made by the feeding mechanism. Noise inherent in the arc has been shown to be connected with the negative used and it increases particularly rapidly as the current through the negative rises through the region of 80-100 amperes. The rate of increase in this region is so disproportionately high that a diminution of noise occurs when two negatives, each carrying 75 amperes, take the place of one negative carrying 150 amperes in the 16 mm. spotlight.

The noise arising from the feeding mechanism can be kept low by careful attention to details of design, such as the use of suitable flexible mountings to provide acoustic insulation for the shafts turning at high speed. Such acoustic insulation is of importance in that it diminishes the amount of vibration reaching the sheet metal work of the housing and so prevents the latter acting as a sounding board. It is the usual practice to mount the motor and first gear box on the same flexible mountings thereby insulating the noisiest components from the remainder of the lamp.

The design of the motor is also of importance from the point of view of silence, for if precautions are not taken to reduce to a minimum magnetic hum, clicks from the bearings, and chatter from the brushes, the noise from these sources alone will be more than can be tolerated. The effect of different types of brushes on the noise from a motor is shown in Fig. 15, in which oscillograms illustrate the total noise from a motor fitted with various brushes. They show that an unsuitable grade of brush may increase the intensity of the total motor noise by a considerable amount.

(6) Compact Source Lamp Units

(6.1.) Colour Rendering Properties of Discharge Lamps

The compact source type of high pressure discharge lamp which is becoming important in motion picture studio lighting is well known in its general form, and it has been recognised for several years that it provided a light source of great potential value to the motion picture industry. (6) (21) (22) (23)

The three main factors which determine the improved radiation properties of the modern as compared with the earlier lamps, depend on the high pressure and loading (watts per cm. of arc) at which the lamps operate.(8) These three factors are:—

1. Relative strength of the spectral lines;
2. Continuous (background) radiation;
3. Effect of adding elements such as cadmium and zinc.

As pressure and loading in the discharge increase, the relative strengths of the spectral lines alter, and the amount of continuous radiation increases. Both effects tend to reduce the predominant blue-green colour of the mercury vapour discharge. Adding cadmium and zinc can increase the energy in the red part of the spectrum, but can only do so efficiently at high pressure and loading. The lamps referred to in this paper (except where otherwise stated) are compact source mercury-cadmium lamps, operating at about 10 atmospheres pressure with an arc voltage drop of some 50 V/cm. The red ratio of the lamps is about 10 per cent. as measured by the percentage of total light which passes

* A noise about as loud as the rustle of leaves disturbed by a gentle zephyr.

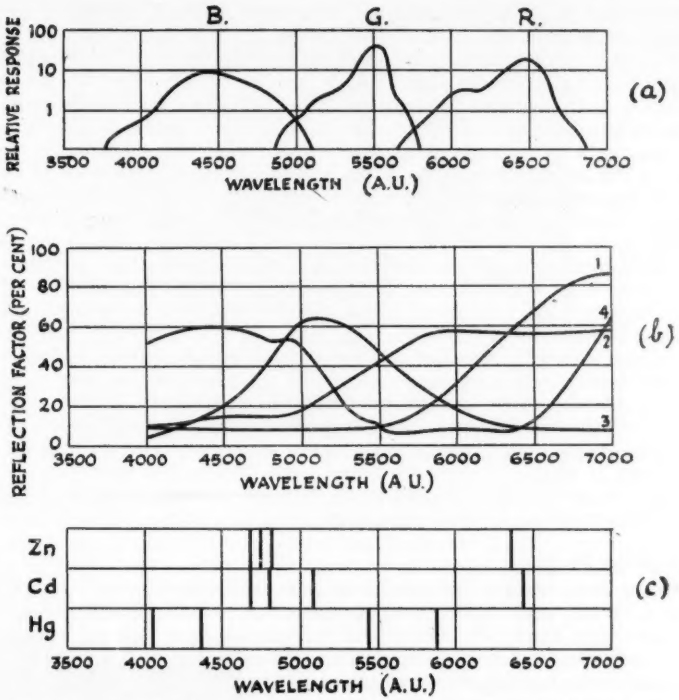


Fig. 16. Response of colour film, reflection factors, coloured materials and mercury, cadmium and zinc spectra.

(a) Relative response of Ansco recording colour film.
(b) Reflection factors for 1. English Vermilion; 2. Yellow Ochre; 3. Emerald Green; 4. Cobalt Blue.
(c) Positions and principal lines of mercury, cadmium and zinc spectra. Relative strengths and amount of continuous background not shown.

through a Wratten No. 25 filter; daylight gives about 15 per cent. on the same scale.(22) (23) (24)

Even with the modifications to colour so far mentioned, however, the discharge lamp does not give either an exact visual colour match to the high-intensity arc or the same colour rendering properties. Fortunately this is not essential since the response of colour film is not identical with that of the eye, and the characteristics of the Technicolor process are such that the differences do not show to a marked extent in the final film. The three emulsions in three-colour subtractive processes respond over fairly broad bands of colour, and, in addition, objects all reflect light over broad bands. Hence there are many possible ways in which the spectral energy distribution of the source might be arranged to give an acceptable colour rendering on film. Fig. 16 shows the broad spectral distributions involved, together with the main (visible) lines in the mercury, cadmium, and zinc spectra.(8)

(6.2.) Operational Requirements

Assuming, then, that the colour-rendering properties of these lamps are satisfactory, there are two considerable operational difficulties to be overcome. When a lamp is switched on from cold it takes several minutes to reach full

brightness, and if a lamp is switched off momentarily, it is difficult to restrike the lamp while it is hot.

When the lamp starts from cold it must, of course, be supplied with sufficient heat to reach its operating temperature, which is of the order of 1,000 deg. C. If electrical energy could be supplied sufficiently rapidly this heating-up process could be short, but in the initial stages of run-up, the discharge passes a large current at low voltage and the permissible current is limited by the seals of the lamp. Thus it is not possible at present to reach full output in less than a few minutes, and it is also difficult to provide sufficient heat from outside the lamp. The method being tried, therefore, is to "simmer" the lamp by keeping it hot all the time it is likely to be wanted, by enclosing it in a small container and heating by operating at low wattage or with external heaters; such external heaters are a part of the lamp ballast circuit.(8) (22) (24)

Several methods have been suggested for striking a lamp which is still hot; these include the application of high-voltage alternating current of low power, an incandescent auxiliary electrode, and a high voltage pulse as from a pulse transformer. Combinations of these methods may be used. Whatever method is adopted, however, introduces extra complication, and, since studio supplies are very reliable, it may well prove unnecessary to fit such devices to all equipment, particularly where the lamp wattage is low, so that its natural cooling time is short. It may be noted here that a low energy high voltage pulse may be used to start a cold lamp, but the voltage required is only some 3 kv., as against about 10 times this value for a hot lamp.(8) (22) (24)

(6.3.) Types of Fittings

Fittings using compact source lamps may be divided into the two classes of general diffusing and directional equipment, the light distribution required from each type being similar to that of the corresponding arc equipment. For example, the unit shown in Fig. 17 is designed to give the same distribution as the white flame arc unit generally used for floodlighting. It incorporates a 2½-kw. lamp, and semi-matt aluminium reflector system, and, if required, a diffusing (lined) front glass. The performance is comparable with the 40-ampere white flame arc unit.

The lamp takes some three minutes to run-up from cold, and in order that it may be held in readiness for immediate use the principle of "simmering" is employed. The two side wings of the reflector are arranged to hinge about a vertical axis so that they can close round the lamp to form a roughly triangular chamber, of which the rear reflector forms the third side. Closing the reflectors to form this chamber automatically introduces extra resistance into the lamp circuit and reduces the wattage to about 1,000. In these

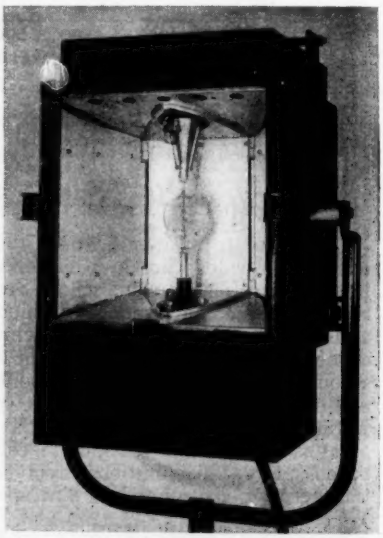


Fig. 17. Floodlight type unit for 2½ kw mercury-cadmium discharge lamps. Front glass removed.

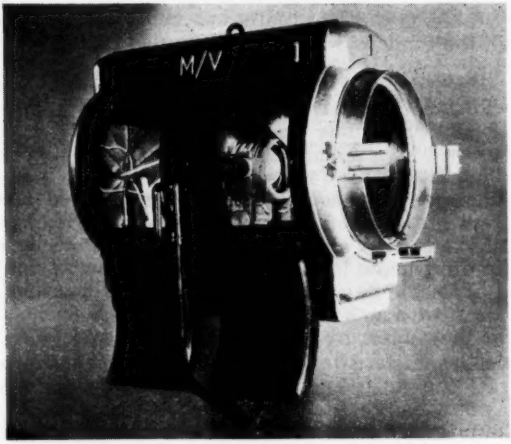


Fig. 18. Experimental spot light for 5 kw mercury-cadmium discharge lamp.

conditions the lamp "simmers" until the shutters are opened, when the series resistance is reduced, and the lamp wattage immediately rises to 2,500. Thus as far as the director and cameraman are concerned the light is available immediately on demand, and for the lamp operator the lever opening or closing the shutters replaces an on-off switch. The cost of power consumed during "simmering" is far outweighed by the time saved.

The 2½-kw. lamp in this unit is started by a high voltage pulse of some 5 kv., produced by rapidly interrupting a direct current flowing in an inductance. The pulse is not lethal since the power is low, and its wave-form is such that a small capacity condenser presents only a low impedance. The fitting is earthed by connecting a condenser between the frame of the fitting

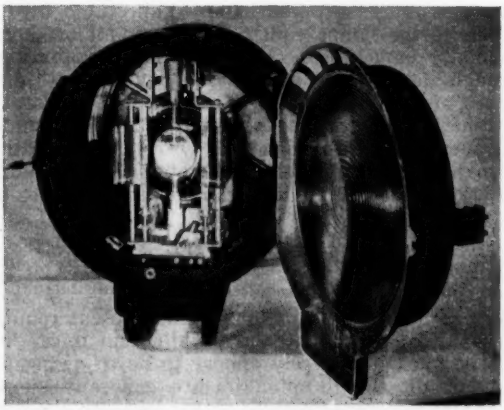


Fig. 19. Experimental spot light unit for 10 kw mercury-cadmium discharge lamp. (Container shutters open.)

and one supply cable so that any pulse appearing on the frame is conducted to earth through the condenser and the distributed capacity of the cables.

Interlocks are provided so that:—

(1) The lamp cannot be switched on with the shutters open, and the shutters cannot be opened unless the lamp is fully run-up. This ensures that the fitting cannot be used unless the lamp is run-up.

(2) If the mains polarity is reversed a red lamp shows.

Fittings using prismatic lenses and compact source lamps are also in use. Fig. 18 shows one for a 5-kw. lamp. The "simmering" principle is again used here, but the lamps are also kept warm by a heater element. The 10-kw. lamp gives, with a prismatic lens, a light distribution comparable with that of the 150-ampere arc. In the fitting of Fig. 19, "simmering" is effected by enclosing the lamp in a cylindrical container which opens in four parts to expose the lamp: the simmering wattage is about 1 kw.

The radiation characteristics of a compact source lamp are such that it raises the refractor plate temperature more than does a high intensity arc lamp of equal wattage. This tends to limit the nearness of arc to lens and hence the pick-up angle. A curved lens is helpful, particularly with large lamps, in serving to keep down the size of the fitting.

But, if compact source lamps are hard on glass, they are kind to the artists, for the glass removes so much radiant heat that the artist is appreciably cooler under a given illumination from compact source lamps than from tungsten or high intensity arc lamps. When illuminations of the order of 1,000 L/sq.-ft. are being considered, the radiant heat is a matter of some importance.

Water-cooled lamps would, of course, remove most heating problems as such, but would introduce many other difficulties. It is not inconceivable that water-cooled lamps will at some time be used in motion-picture studios (as they have been for television[8] [24]), and work on them continues; a new form of some interest has recently been demonstrated.[25] However, it seems unlikely that the technical problems associated with water-cooling on the large scale in studios will be quickly overcome.

Two precautions must be taken in any film studio fitting using compact source lamps. Since the lamps emit a large amount of short-wave radiation which is erythemally dangerous, no light must emerge from the fitting unless it has passed through glass or has suffered inter-reflections to reduce its intensity practically to zero, as with well-designed louvres. Since, also, the lamps operate at above atmospheric pressures the possibility of a burst must be anticipated and the fitting and glassware designed to withstand it. Although the chance of a burst is small and will decrease as lamp-making techniques improve, no good could come of an accident which caused broken pieces of refractor plate to fall on the stage.

(7) Supplies for Studio Lighting

(7.1.) Nature and Amount of Power Required

Steady and continuous illumination is the present requirement for satisfactory photography of a set, and the illumination must, in fact, be steady and continuous; it must not merely appear to be so owing to the persistence of vision. As a result the illuminators are generally supplied with direct current, to avoid stroboscopic effects occurring between the camera shutter and cyclic variations in the output of light. Sufficient current is required to light all the stages likely to be used simultaneously. A large stage may require

about 20,000 amperes at 115 volts, and to fulfil such demands it is usual to install in a conveniently sited central station, generating or conversion equipment to supply all the stages by means of a three-wire D.C. distribution system with 230 volts between the outer busbars. The output of the central station, which will vary with the maximum number of studios to be supplied, may be some 5,000 kilowatts. It is also necessary for the voltage to be well regulated so that there are no sudden changes in the illumination of a set while the shot is actually being taken. All of the three types of lighting fitting have a light output that is sensitive to changes in voltage; a 5 per cent. variation in voltage producing a 10 per cent. to 15 per cent. change in peak candles.

(7.2.) Ripple of the Supply Voltage

Most commercial D.C. supplies do not furnish a perfectly steady voltage, but one which has a ripple, for these supplies are invariably obtained by rectifying alternating current or by the use of orthodox generators. Unless precautions are taken to eliminate it, there will be a ripple voltage arising either from incomplete smoothing of the rectified alternating current or from the disturbance to the magnetic field of the generator caused by the armature slots. Generally, the presence of this ripple is immaterial, but this is not the case in a studio where a sound recording is being made, because any conductor carrying the rippled supply will, if it is free to vibrate, act as a form of loudspeaker and emit an audible note corresponding in frequency to the ripple frequency. The flame of the carbon arc is a good example of such a conductor, it is free to vibrate and is capable of responding to a wide range of frequencies, possibly wider than the audible range. It is also comparatively sensitive, and tests have shown that at some frequencies the ripple voltage must be reduced to a few millivolts before the arc is sufficiently quiet for use in the making of sound films. The minimum audible ripple voltage for a 150-ampere arc using a 16-mm. positive varies with frequency in a way similar to the variation in sensitivity of the ear. At 50 cycles as much as 500 millivolts is required before an audible note is produced, but this drops rapidly with increase of frequency, so at 300 cycles per second, the limit is 20 millivolts falling to a flat minimum of about 5 millivolts at 3,000-6,000 cycles, and rising again as the upper limit of audibility is reached to 15 millivolts at 10,000 cycles.(26)

It is not always convenient to use generators whose ripple content is as low as that required for silent operation of the arc, and in the case of a rectifier the ripple of the supply immediately after rectification is considerable. Both generators and rectifiers, however, can have their output adequately smoothed by chokes and condensers arranged either as a low-pass aperiodic filter or, less commonly, as a tuned filter, and the resulting supply can then be used for arc lamps with satisfactory results.(27)

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Discussion

Mr. CHARLES HILLYER after congratulating the authors on the entertaining manner in which the paper had been presented, asked if they thought there would be any developments on incandescent lighting for black and white photography. The paper had concentrated on the higher ranges of illumination which, of course, were mainly used for colour photography, but in view of the fact that the present incandescent lighting fittings were designed in 1934, and there had been little change since, he wondered whether any improvement could be looked for in the future. Although the fittings had changed in size and weight the amount of light coming from them had remained more or less constant. Motion picture photography has certainly not stood still since 1934 and he wondered whether the authors could envisage any development in this field.

Mention had been made in the paper of attaining a suitable "balance." Those who had spent all their lives in the work of lighting on the screen and stage, knew that the first thing they were taught was that in presenting entertainment to the public it must be the object or person that they wished to emphasise that had to be illuminated so that the part of the picture or setting which caught the eye first was the part that the photographer wished them to concentrate their attention on. That was the aim of every cinematographer and it must be done not in a way that "hits you" but quite surreptitiously.

It was of the utmost importance that the correct "balance" should always be obtained, and whilst some photographers achieved the object with practically no light at all, others required every possible piece of lighting equipment that could be pressed into service, and there lies a problem for the film studio engineer in estimating the requirements of a production.

The authors made no comments on the use of coloured gelatines in front of the arc lamps. He brought this forward for discussion as some years ago he was associated with Mr. Hauser in making a film in which colour gelatines

were used quite extensively in front of the lights. This particular film was a fantasy and if a tree in the background was, for example, brown or green and the photographer thought it would look much nicer pink, the colour of the tree was changed to pink by the introduction of a colour gelatine in front of the arc or arcs which were used. Of course, this type of film did lend itself to such practices. He had been recently associated with a production in which practically the whole of the sky backings were lit by this method. This production consisted mainly of exteriors built inside, and the settings were usually grass, trees and enormous sky backings. These backings were usually painted white and different types of sky were achieved by using a wide range of colour gelatines in front of the arcs to produce a suitable sky for whatever time of day or night that the photographer wished to record.

In some cases as many as 40 150-amp. arcs, each carrying a colour gelatine in front, were in use at one time for this type of work. The difficulty, however, in the use of this development of lighting for colour photography was that there are no known commercial gelatines which, after being in front of an arc lamp for more than a few minutes, did not bleach and change colour. This was, of course, another headache added to the studio engineer's problems. the authors might be able to give details of the latest developments.

An interesting feature of the whole studio production lighting problem was, that whereas there had been very great improvements in the technique and equipment side of motion picture photography, the same could not be said of the lighting side of the problem. When he first went into the industry the film stock was extremely slow and variable, and lens apertures were never larger than f4.5. Now film stock is treble its speed and lens apertures of f1.9 and f1.5 were quite common in the studios to-day.

With these improvements one would have thought that the amount of light would be considerably less, but the reverse had happened, and he was providing considerably more light than used to be necessary in the past. It appeared that there was nothing logical that would fit any sort of rules in the film industry, or at least that section of it that applied to the illuminating engineer. He would like to recall a statement made by Mr. Stevens some long time ago, that it did not seem to matter what wonderful ideas and economies had been put into getting the best possible light to come out of a lamp, as soon as a lamp was put into operation the studio people would immediately commence to use all sorts of ingenuity and ideas to fit diffusers, etc., on the front to keep the light back in the lamp house. This was a typical example of why no rules would seem to apply to the problems concerned with the illumination for motion picture photography.

In conclusion he stated that the authors had presented a picture from which it would appear that the lighting for motion picture photography was an extremely well organised and efficient business, when the real facts were, that the whole job calculated by the terms of any slide rule engineer could best be referred to as a "mad house." This would be a coarse but very apt description of the organisation when viewed by somebody outside the industry.

MR. BAYNHAM HONRI said he was concerned with a studio which until recently dealt only with black and white films but which had now turned over to colour film production. The amount of light required for colour work was about five times that previously used with black and white photography. This necessitated the use of a greater number of arcs all of which gave off a certain amount of heat and smoke, and with the existing ventilation, the whole

stage was filled with smoke. This was overcome by installing additional large extractor fans.

Some of the H.I. arc lamp housings did not emit a great deal of smoke, but were subject to a deposit inside the housing. Other H.I. housings, more efficiently ventilated, kept cleaner and cooler, but tended to fill the studio stage with smoke. He asked for the authors' views on this question of studio lamp housing ventilation.

PROFESSOR J. T. MACGREGOR MORRIS, referring to colour rendering asked whether in a colour film it was desired to bring out the scene as it really was, or was it desired to bring out some special colours? The reason he asked this question was because he had on one occasion been discussing with a well known artist how far a photograph of a man would help the artist to make a good picture. This artist said it would help, but only to a slight extent. He said it was apt to lead him astray because when an artist looked at any particular person he saw something in that person which he wished to emphasise. In fact, the artist deliberately distorted in order to bring out that particular characteristic. Therefore, there was the question of whether a similar kind of thing was wanted with colour photography.

There was also the point that when a person was in the habit of listening to a programme on his own wireless set he got the impression that reception was perfect and when he listened on another and perhaps better set he would say this other set was defective. The reason was that he had become accustomed to a certain lack of quality. They had seen on the screen comparative pictures of a person illuminated by two sources of light, but in addition it would have been even better to have seen that individual in person beside the pictures. That was the only way to make a true comparison.

With regard to arc noise he said that if a pulsating current was sent through an arc it responded by expanding and contracting and it was that expanding and contracting at the musical frequency that actually threw off a sound wave into the air. The question, therefore, was whether we should try to relate this to voltage or to current. He suggested that for scientific purposes it should be related to current because that was the fundamental thing which made the arc throw out sound. For this reason he thought that it would be valuable if the curve shown by the authors dealing with the effect of ripple showed the minimum percentage current change.

MR. T. E. KNIGHT said it would be interesting to hear some of the current loading of the stage sets shown on the slides, and perhaps Mr. Hauser would quote from memory some maximum loadings on the largest sets.

MR. L. G. APPLEBEE referring to the use of colour media with a white background, mentioned by a previous speaker, asked the authors whether in the film studio coloured media was used to enhance any particular colour. It was known to be done in America. He believed the film of Abraham Lincoln was actually taken in the White House where the hangings and tapestries and furniture were of a very dull colour and of great age, but coloured media were used in front of the lighting units to bring out the colours more clearly. He had also been told that Walt Disney used colour media for light projected down on to his drawing.

Had any attempt been made to use fluorescent paints on costumes and then to use the black lamp to reveal the fluorescence? That was done in the theatre and it occurred to him that it might have an important application in building

up certain colours in photography. Fabric manufacturers were now producing materials such as artificial silk that fluoresced and in many theatre shows, both in London and New York, the " black lamp " was being used at the *same* time as the normal lighting.

MR. J. G. HOLMES congratulated the cinema industry on the very ready manner in which it had assimilated some of the ideas of photometry. It fell to his lot some five or six years ago to meet a technical committee, of which Mr. Hauser was chairman, and of which Mr. Hillyer was a member. That committee knew a lot about light values and he knew something about photometry, but there was very little overlap. It was quite a thrill when Mr. Hillyer plotted a polar curve in the studio in which they were then working, and he remembered Mr. Hauser working out lens factors, which could be regarded as quite a novelty in those days.

A number of new terms had been mentioned during the meeting and he thought they should acknowledge the manner in which the cinema studio technicians had accepted and had learned to use some of the illuminating engineer's terms. Incidentally, he asked if the word " illuminator " was correctly given in the script, because it was not used in the industry and it was new to him.

DR. J. N. ALDINGTON asked for some information with regard to the double negative arc which the authors had described. Had that arc a positive resistance characteristic? It would appear that at least it was not so negative as the ordinary arc in view of the fact that the authors had been able to run two in series at 115 volts with a total drop of voltage across the two of 100.

Personally he found considerable satisfaction in keeping in touch with developments in the use of the mercury-cadmium-zinc arc for this class of work because it was seriously suggested only four or five years ago that work which had been carried out in this country on that type of lamp should be brought to a conclusion because of the very considerable difficulties encountered during the development of the higher power lamps. Fortunately, however, the work was continued, and work which was originally sponsored in time of war was now being carried forward in time of peace. As the work proceeded he was confident that the difficulties which were always associated with a new development such as that of the high-power M.E. lamps would be gradually overcome and that this new source would find increasing use. It was interesting to see the happy coincidence of the main spectral lines of the mercury-cadmium-zinc arc with the three-colour process response of the Technicolor system, but whilst that coincidence existed it was nevertheless necessary to continue to look for sources giving a greater continuous radiation, because as colour photographic processes developed it might well be that these would require a nearer approach to black body radiation.

Referring to Table 4 and the effective efficiency of the light sources in terms of energy from the generator, he said he had made this point at previous meetings on other subjects because as one associated with the sources themselves he was interested in any means by which the light produced by a source could be applied more effectively to the subject to be illuminated. In Table 4 it seemed that in the case of studio lighting only some 3 lumens per watt out of the 50 of the arc actually appeared on the set.

He was interested not only in considering the most effective utilisation of the light but in the special design features of the lamps themselves because any lamp which inherently allowed greater utilisation was a step forward,

although there might not be an increase in the efficiency of the light source itself. It was obvious that in matters of this sort it was not the luminous efficiency measured in a photometric integrator that was important but the lumens which could be effectively utilised.

MR. E. J. G. BEESON referring to the high pressure mercury vapour lamp said that it had been known for some little time that this lamp might be a very useful source for the lighting of film studios, but it was not until the colour modified lamp was introduced that a reasonably correct reproduction in colour could be obtained with Technicolor or other allied processes. Tests carried out with a 5kw, single-ended colour modified lamp in May 1945, showed the great possibilities of this new light source. Mr. Hauser immediately followed this up with a larger scale trial and very much large scale trials were now under way with the original type of lamp. The results are awaited with very great interest and may mark a turning point in the history of film studio lighting. It may be rather early at this stage to predict the general trend and the future of these lamps, but he asked the authors their opinion as to the lamp power and numbers that were likely to be required for the lighting of an average Technicolor set of to-day.

MR. HAUSER, replying to the discussion, and dealing first with Mr. Applebee, said that colour was used very extensively in the studio for Technicolor photography. With regard to Mr. Hillyer's remarks on coloured media, he said that experiments were being carried out now with the object of improving such media so that it could be used for days at a time instead of for half an hour as at present.

As to whether the term "illuminator" was used in the studio—asked by Mr. Holmes—he said it was not, so far as his knowledge went, but back in the middle '20s the Germans brought out a series of arc lamps with faceted mirrors. They were made by a firm in Berlin and were used in all the big German films of the period and were styled "Illuminators." He believed that was the origin of the term, but there was no reason, as far as he could see, why any piece of lighting equipment should not be called an "illuminator."

Mr. Beeson had put a difficult question and it could not be answered fully at the moment. It was clear that before the mercury-cadmium-zinc lamp could be used extensively there would have to be a much larger range of lamp capacities. Certainly, sets which the cinema industry was used to taking would require lamps by the hundred in different sizes, and it was a little early to be prophetic about this new lamp.

As regards the current readings asked for by Mr. Knight, he said that in the case of the film "The Thief of Bagdad," the total loading on some of the sets was 22,500 amperes at 115 volts. He also knew of loadings of 20,000 amperes at 115 volts. These were the highest figures he was aware of as being employed in this country.

DR. F. S. HAWKINS, replying to some other points mentioned in the discussion, first referred to the question of fumes raised by Mr. Honri and said that the work carried out by the authors was on the basis that ventilation should fulfil two objects: it should keep the fitting cool and should avoid the deposition of fumes on surfaces, particularly on the back of the refractor, where they would interfere with the distribution of the light. In the designs now being developed louvres were used which effectively stopped the primary light from getting out of the fitting, whatever

position the arc was in, but they allowed a certain amount of secondary reflected light to emerge. This light, although harmless and unimportant from the point of view of illuminating the set, lit up what fume came out of the lamp and made a little look like a lot. It was necessary to arrive at the happy compromise which achieved reasonably good ventilation and at the same time did not lose too much light.

With regard to Professor MacGregor Morris and the use of voltage or current to specify the ripple, the designer of the generator must think in terms of the ripple voltage at the generator terminals, and practical experience suggested that the results obtained from the arc were most useful when expressed in terms of ripple voltage. However, in making these experiments the author also measured the ripple current, and it was found that the curve of the ripple current against frequency was not unlike that of the voltage. There were changes in impedance but they were not great.

In reply to Dr. Aldington, there was a well founded impression that the carbon arc had a negative characteristic, and this was true in the case of the low intensity arc, two solid sticks of carbon connected to a d.c. supply in the ordinary manner. In the case of the high intensity arcs it was not true. Most of these arcs had a weakly positive or a weakly negative characteristic, and it was even possible to get a zero characteristic; however, in the case of the double negative arc, the characteristic was distinctly positive.

MR. W. R. STEVENS, making the final reply, told Mr. Hillyer that he could not see any radical improvement likely in tungsten lamp fittings, although there would probably be detailed improvements. The tungsten lamp as far as could be seen—and many people had said this—was very close to the end of its development. It might be worth while sometimes to over-run the lamps, but there seemed to be no optical systems appreciably better than the prismatic lens type.

The mercury-cadmium-zinc discharge lamp source appeared to have an enormous future, although a great many things have yet to be learned about it. As Dr. Aldington had said, efforts must be made to get more continuous radiation. Whether that would come in the compact source type of lamp or whether it would come in the gas-arc lamp which Dr. Aldington described could not be said at the moment.

Professor MacGregor Morris asked the very interesting question, "Did we wish to reveal colours as they really were?" Mr. Stevens thought the answer was emphatically "No." Artists attempted to show life as they saw it and not necessarily as it appeared to others. Nevertheless, the technician in providing tools for the artists must try to make possible an exact reproduction, leaving the licence for distortion to the artist.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form :—"Trans. Illum. Eng. Soc. (London)."

SESSIONAL MEETING IN LONDON

A sessional meeting was held at the Lighting Service Bureau at 6 p.m. on Tuesday, April 13, 1948, when the President (Dr. J. W. T. Walsh) took the chair.

The minutes of the last meeting having been taken as read and approved, the President called upon Mr. F. V. Hauser, Dr. F. S. Hawkins and Mr. W. R. Stevens to present their paper, entitled "Photographic Illumination in Motion Picture Studios." The authors reviewed the basic requirements for cinema studio lighting and demonstrated many types of lamps and equipment which were used. The latest types of carbon arc units and compact source lamps were demonstrated and described, and a number of interesting demonstrations were carried out to show their colour rendering properties. The authors also showed a number of slides of film studio sets and colour films taken by means of various types of light source.

After a vote of thanks, proposed by the President, had been carried, the discussion was opened by Mr. Charles Hillyer, who was followed by Mr. Baynham Honri, Professor J. T. MacGregor Morris, Mr. T. E. Knight, Mr. L. G. Applebee, Mr. J. G. Holmes, Dr. J. N. Aldington, and Mr. E. J. G. Beeson. The authors replied in turn to the discussion and the meeting was closed.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members :—

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STUDENT MEMBER:—

Williams, E. J. .....c/o Mrs. Fish, 51, Wheatfield Road, Old Bilton, Rugby, WARWICKSHIRE.

Register of Lighting Engineers

The following applications for inclusion on the Register of Lighting Engineers have been accepted :—

S. Addison.
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W. Imrie-Smith.
J. Martin.
R. Montgomery.
A. J. Ogle.
F. J. Palin.
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